# FALL3D 5.1

***Computer Code and Related Documentation***

Giovanni Macedonio, Arnau Folch and Antonio Costa

Istituto Nazionale di Geofisica e Vulcanologia
Sezione "Osservatorio Vesuviano"
Via Diocleziano 326 -80124 Napoli, Italy

January 2008

# Contents

**1 Introduction** **3**
1.1 Governing equation . . . 3
1.2 Parameterisation of the Eddy Diffusivity Tensor . . . 3
1.3 Settling velocity models . . . 4
1.4 Meteorological variables and topography . . . 5

**2 Solving algorithm and code paralellization** **5**

**3 Program setup** **6**
3.1 Installation . . . 6
3.2 Folder structure . . . 7
3.3 FALL3D 5.1 program run . . . 7

**4 The FALL3D 5.1 input files** **8**
4.1 The control file `FileInp` . . . 8
4.1.1 BLOCK TIME_UTC . . . 8
4.1.2 BLOCK FALL3D . . . 8
4.2 The source file `FileSrc` . . . 9
4.3 The granulometry file `FileGrn` . . . 9
4.4 The database file `FileDbs` . . . 9

**5 The FALL3D 5.1 output files** **10**
5.1 The log file `FileLog` . . . 10
5.2 The results file `FileRes` . . . 10

**6 The utility programs** **11**
6.1 The program SETGRN . . . 11
6.1.1 Program execution . . . 11
6.1.2 The GRANULOMETRY block . . . 11
6.2 The program SETDBS . . . 11
6.2.1 Program execution . . . 12
6.2.2 The METEO_DATABASE block . . . 12
6.2.3 The meteo data file `FileDat` . . . 13
6.2.4 The topography file `FileTop` . . . 13
6.3 The program SETSRC . . . 13
6.3.1 Program execution . . . 14
6.3.2 The SOURCE block . . . 14
6.4 The program FALL3DPOSTP . . . 15
6.4.1 Program execution . . . 15
6.4.2 The POSTPROCESS_MODELS block . . . 15
6.4.3 The symbols file `FileSym` . . . 16

**7 References** **17**

# 1 Introduction

FALL3D 5.1 is a code written in FORTRAN90 which circumvents most of the simplifications behind the simpler volcanic ash fallout models. The model solves the time-dependent 3D advection-diffusion-sedimentation equation by means of a finite differences explicit scheme using a regular mesh. It uses the gradient transport theory to evaluate the atmospheric turbulent diffusion within and above the Atmospheric Boundary Layer (ABL) and experimental fits for the particle settling velocities, in addition to values from a dataset that contains full 3D prognostic wind field, source term, and topography. The model can, consequently, be used to forecast either ash concentration in the atmosphere or ash loading on the ground. Both serial and parallel versions are included with the package.

## 1.1 Governing equation

The non-conservative form of continuity equation written in a generalised coordinate system $(X, Y, Z)$ is:

$$\begin{aligned} &\frac{\partial C}{\partial t} + U\frac{\partial C}{\partial X} + V\frac{\partial C}{\partial Y} + (W - V_{sj})\frac{\partial C}{\partial Z} = -C\nabla\cdot\mathbf{U} + C\frac{\partial V_{sj}}{\partial Z} \\ &\frac{\partial}{\partial X}\left(\rho_* K_X \frac{\partial C/\rho_*}{\partial X}\right) + \frac{\partial}{\partial Y}\left(\rho_* K_Y \frac{\partial C/\rho_*}{\partial Y}\right) + \frac{\partial}{\partial Z}\left(\rho_* K_Z \frac{\partial C/\rho_*}{\partial Z}\right) + S_* \end{aligned} \tag{1}$$

where $C$ is the scaled average concentration, $(U, V, W)$ are the scaled wind speeds, $K_X, K_Y$ and $K_Z$ are the diagonal scaled diffusion coefficients, $\rho_*$ the scaled atmospheric density and $S_*$ is the source term in the generalized coordinate system. Considering as a frame of reference a simple terrain-following coordinate system where the horizontal coordinates remain unchanged with respect to the Cartesian $(x = X,\ y = Y,\ z \to Z)$, the scaling factors are those reported in Table 1. Equation (1) is solved for each particle velocity class independently, *i.e.* assuming no interaction between particles belonging to different classes during the transport process. The generic particle class $j$ is defined by triplet of values characterizing each particle $(d_p, \rho_p, F_p)$, that are, respectively, diameter, density, and a shape factor. For $d_p$ we use the equivalent diameter $d$, which is the diameter of a sphere of equivalent volume. For the shape factor $F_p$ we choose the sphericity $\psi$, which is the ratio of the surface area of a sphere with diameter $d$ to the surface area of the particle. In our approximation, each triplet $(d, \rho_p, \psi)$ is sufficient to define the settling velocity value $V_{sj}$.

## 1.2 Parameterisation of the Eddy Diffusivity Tensor

In order to solve equation (1) it is necessary to evaluate the vertical and horizontal diffusion coefficients. Inside the atmospheric surface layer, the Monin-Obukhov similarity theory estimates the vertical turbulent diffusivity $K_z$ in terms of the friction velocity $u_*$, and the Monin-Obukhov length $L$:

$$K_z = \frac{\kappa z u_*}{\phi_h} \tag{2}$$

where $\kappa$ is the von Karman constant ($\kappa = 0.4$), $z$ is the distance from the ground, and $\phi_h$ is the atmospheric stability function (e.g. Jacobson, 1999). Above the surface layer, the original form of the Monin-Obukhov similarity theory is no longer valid. In order to extend this theory to the entire boundary layer ($z/h < 1$) an evaluation of the Atmospheric Boundary Layer (ABL) height $h$ is required. For this purpose, FALL3D 5.1 uses a simple parameterisation valid on the entire ABL (Ulke, 2000):

$$K_z = \begin{cases} \kappa u_* z \left(1 - \dfrac{z}{h}\right)\left(1 + 9.2\dfrac{h}{L}\dfrac{z}{h}\right)^{-1} & h/L \geq 0 \quad \text{stable} \\ \kappa u_* z \left(1 - \dfrac{z}{h}\right)\left(1 - 13\dfrac{h}{L}\dfrac{z}{h}\right)^{1/2} & h/L \leq 0 \quad \text{unstable} \end{cases} \tag{3}$$

Note that in the neutral case ($L \to \infty$) both expressions coincide. Finally, in the free atmosphere above the ABL ($z/h > 1$), $K_z$ is considered a function of the local vertical wind gradient, a characteristic length scale $l_c$, and a stability function $F_c$ depending on the Richardson number $Ri$:

$$K_z = l_c^2 \left|\frac{\partial V}{\partial z}\right| F_c(Ri) \tag{4}$$

For $l_c$ and $F_c$ the model adopts the relationship used by the CAM3 model (Collins et al., 2004) of the National Center for Atmospheric Research (NCAR):

$$l_c = \left( \frac{1}{\kappa z} + \frac{1}{\lambda_c} \right)^{-1} \tag{5}$$

$$F_c(Ri) = \begin{cases} \dfrac{1}{1+10Ri(1+8Ri)} & \text{stable} \quad (Ri > 0) \\ \sqrt{1-18Ri} & \text{unstable} \quad (Ri < 0) \end{cases} \tag{6}$$

where $\lambda_c$ is the so-called asymptotic length scale ($\lambda_c \approx 30$m) while the Richardson number is calculated as $Ri = \dfrac{g}{\theta_v} \dfrac{\partial \theta_v / \partial z}{|\partial V / \partial z|^2}$ (with $\theta$ being virtual potential temperature).

On the other hand, for the horizontal eddy diffusivity $K_H = K_x = K_y$, FALL3D 5.1 assumes a large eddy parameterisation as that used by RAMS model (for $\Delta z / \Delta \ll 1$ ) (Pielke et al., 1992):

$$\begin{aligned} K_H &= R \max \left( K_{mh}; (C_{SH}\Delta)^2 \sqrt{\left( \frac{\partial v_x}{\partial y} + \frac{\partial v_y}{\partial x} \right)^2 + 2 \left[ \left( \frac{\partial v_x}{\partial x} \right)^2 + \left( \frac{\partial v_y}{\partial y} \right)^2 \right]} \right) \\ K_{mh} &= 0.075 K_A \Delta^{4/3} \end{aligned} \tag{7}$$

where $\Delta = \sqrt{\Delta x \Delta y}$, $C_{SH}$ is a dimensionless constant ranging from 0.135 to 0.32, $K_A$ is a user defined parameter close to one, and $R \simeq 3$.

## 1.3 Settling velocity models

There are several semi-empirical parameterizations for the particle settling velocity $v_s$ if one assumes that particles settle down at their terminal velocity:

$$v_s = \sqrt{\frac{4g\left(\rho_p - \rho_a\right) d}{3 C_d \rho_a}} \tag{8}$$

where $\rho_a$ and $\rho_p$ denote air and particle density, respectively, $d$ is the particle equivalent diameter, and $C_d$ is the drag coefficient. $C_d$ depends on the Reynolds number, $Re = d v_s / \nu_a$ ($\nu_a = \mu_a / \rho_a$ is the kinematic viscosity of air, $\mu_a$ the dynamic viscosity). In FALL3D 5.1 several options are possible for estimating settling velocity, such as:

1. `ARASTOOPOUR` model (Arastoopour et al., 1982):

$$C_d = \begin{cases} \dfrac{24}{Re}(1 + 15 Re^{0.687}) & Re \leq 10^3 \\ 0.44 & Re > 10^3 \end{cases} \tag{9}$$

   valid for spherical particles only.

2. `GANSER` model (Ganser , 1993):

$$C_d = \frac{24}{Re K_1} \left\{ 1 + 0.1118 \left[ Re \left( K_1 K_2 \right) \right]^{0.6567} \right\} + \frac{0.4305 K_2}{1 + \dfrac{3305}{Re K_1 K_2}} \tag{10}$$

   where $K_1 = 3/(1 + 2\psi^{-0.5})$, $K_2 = 10^{1.84148(-\mathrm{Log}\psi)^{0.5743}}$ are two shape factors, and $\psi$ is the particle sphericity ($\psi = 1$ for spheres).

3. `WILSON` model (Wilson and Huang , 1979) using the interpolation suggested by Pfeiffer et al. (2005):

$$C_d = \begin{cases} \dfrac{24}{Re} \varphi^{-0.828} + 2\sqrt{1.07 - \varphi} & Re \leq 10^2 \\ 1 - \dfrac{1 - C_d|_{Re=10^2}}{900}(10^3 - Re) & 10^2 \leq Re \leq 10^3 \\ 1 & Re \geq 10^3 \end{cases} \tag{11}$$

   where $\varphi = (b + c)/2a$ is the particle aspect ratio ($a \geq b \geq c$ denote the particle semi-axes).

4. `DELLINO` model (Dellino et al., 2005):

$$v_s = 1.2605 \frac{\nu_a}{d} \left( Ar\, \xi^{1.6} \right)^{0.5206} \tag{12}$$

where $Ar = d^3(\rho_p - \rho_a)\rho_a/\mu_a^2$ is the Archimedes number, and $\xi$ is a particle shape factor (sphericity to circularity ratio).

Since for FALL3D 5.1 the primary particle shape factor is the sphericity $\psi$, for sake of simplicity, it calculates $\varphi$ in (11) and $\xi$ in (12) approximating particles as prolate ellipsoids.

### 1.4 Meteorological variables and topography

FALL3D 5.1 reads time-dependent meteorological data (wind field, air temperature, Monin-Obukhov length $L$, friction velocity $u_*$, and ABL height $h$) and topography from a database created by an external utility program (SETDBS ). There are two ways to generate this database. The simplest option consists of using a horizontally uniform wind derived from a vertical profile, typically obtained from vertical sounding measurements. The second option, more elaborated, uses data derived from the output of the meteorological diagnostic model CALMET (Scire et al., 2000). The second option is used for assimilating and interpolating short-term forecasts (or re-analysis) from mesoscale meteorological prognostic models. In FALL3D 5.1 , both direct and indirectly effects of topographic relief on tephra fallout can be accounted for. A direct influence of topography is geometrical, since particle travelling distances vary depending on the relief. This is accounted for when point sources are distributed, considering terrain following coordinate. Moreover, topography may alter the wind field locally within the Atmospheric Boundary Layer (ABL), affecting indirectly the transport of volcanic particles near the ground. These effects can be captured by using the database as generated with the CALMET option.

## 2 Solving algorithm and code paralellization

FALL3D 5.1 solves Eq. (1) on a structured grid using a FD explicit algorithm. The mesh is assumed uniform along the horizontal but it can vary along the vertical. The advective terms are discretised using a second-order Lax-Wendroff scheme whereas the diffusive terms are evaluated using a central differences (see Costa et al. (2005) for details). Free flow conditions are assumed at all boundaries of the computational domain (*i.e.* zero normal derivatives for outgoing fluxes and null concentrations for ingoing fluxes). The parallel version of FALL3D 5.1 is based on the Message-Passing Interface (MPI) library. The paralellization of the code is done at two levels, one for the particle classes and another for the domain. First, the processors available are distributed among groups. Each group works on one particle class or on a series of particle classes. Since it is assumed that particles do not interact, the first paralellization is straightforward. Second, if each particle class has more than one processor assigned (*i.e.*, if the number of processors is a multiple of the number of classes), a second parallelization is performed for the vertical layers. The first paralellization (on the classes) scales linearly because broadcast operations are minimum. This is not true for the second paralellization because broadcast operations among processors of a group grow proportionally to the number of processors. The scalability analysis has shown that optimal performance (best ratio between CPU time and number of processors) is achieved when each processor works with 3-4 vertical layers.

# 3 Program setup

The FALL3D 5.1 package comes with a set of utility programs which can be used to generate input files in the format required by FALL3D 5.1 or to postprocess the results. The order of execution is the following (see Figure 1): (i) run the program SETGRN to generate the granulometry file, (ii) run the program SETDBS to generate the database files containing meteorologic and topographic data, (iii) run the program SETSRC to generate the source term file, (iv) run FALL3D 5.1 (serial or parallel version) and, finally, (v) run the program FALL3DPOSTP to postprocess the results. Steps (i) and (iii) can be avoided if the user furnish the granulometry and source files directly.

## 3.1 Installation

- On a Windows OS download and decompress the file `Fall3d-5.1.tar.gz` on your selected directory. The `Fall3d-5.1.tar` file already contains Windows executables for FALL3D 5.1 and the rest of utility programs. It is not strictly necessary to have a FORTRAN90 compiler. The untaring of `Fall3d-5.0.tar` will create the folders described in Table 2.

- On a Unix/Linux/Mac X operating system:

  1. Decompress and then untar the file `Fall3d-5.1.tar` issuing the command "`tar xvf Fall3d-5.1.tar`". This will generate directory `Fall3d-5.1` (see Table 2).
  2. Compile the program FALL3D 5.1 .
     - For the serial version enter the directory `Fall3d-5.1/Sources`, then issue the command "`make`" to produce the executable Fall3d.ser.exe. You can edit the Makefile to select your favourite compiler. After compilation you may issue the command "`make clean`" to remove unneeded files.
     - For the parallel version enter the directory `Fall3d-5.1/Sources_par/comm` and issue the command "`make`" to generate the comm.a library. You need to have MPI installed in your computer. Then enter the directory `Fall3d-5.1/Sources_par` and issue the command "`make`" to generate the executable Fall3d.par.exe.
     - NOTE: If you are not going to run on a Windows platform you can also delete the executable Fall3d.win.exe.
  3. Compile the (optional) utility program SETGRN . Enter the directory `Fall3d-5.1/Utilities/SetGrn/Sources`, then issue the command "`make`" to produce the executable SerGrn.exe. You can edit the Makefile to select your favourite compiler. After compilation you may issue the command "`make clean`" to remove unneeded files. If you are not going to run on a Windows platform you can also delete the executable SetGrn.win.exe.
  4. Compile the (optional) utility program SETSRC . Enter the directory `Fall3d-5.1/Utilities/SetSrc/Sources`, then issue the command "`make`" to produce the executable SerSrc.exe. You can edit the Makefile to select your favourite compiler. After compilation you may issue the command "`make clean`" to remove unneeded files. If you are not going to run on a Windows platform you can also delete the executable SetSrc.win.exe.
  5. Compile the utility program SETDBS . Enter the directory `Fall3d-5.1/Utilities/SetDbs/Sources`, then issue the command "`make`" to produce the executable SetDbs.exe. You can edit the Makefile to select your favourite compiler. After compilation you may issue the command "`make clean`" to remove unneeded files. If you are not going to run on a Windows platform you can also delete the executable SetDbs.win.exe.
  6. Compile the utility program . Enter the directory `Fall3d-5.1/Utilities/ModelPostp/Sources`, then issue the command "`make`" to produce the executable ModelPostp.exe. You can edit the Makefile to select your favourite compiler. After compilation you may issue the command "`make clean`" to remove unneeded files. If you are not going to run on a Windows platform you can also delete the executable ModelPostp.win.exe.

## 3.2 Folder structure

Table 2 shows the folder structure. The directory `Fall3d-5.1/Sources` contains the FALL3D 5.1 serial source files, the directory `Fall3d-5.1/Sources_par` contains the FALL3D 5.1 parallel source files, the directory `Fall3d-5.1/Utilities` contains the programs SETGRN , SETSRC , SETDBS , and and, finally, the directory `Fall3d-5.1/Runs` contains the runs, one within each own folder. An example run named "Example" is provided with the installation.

## 3.3 FALL3D 5.1 program run

- On a Windows OS type
  "`Fall3d.win.exe FileInp FileSrc FileGrn FileDbs FileLog FileRes`"
- On a Unix/Linux/Mac X OS type
  "`Fall3d.ser.exe FileInp FileSrc FileGrn FileDbs FileLog FileRes`"
  for the serial MPI version and
  "`mpiexec -n NCPU Fall3d.par.exe FileInp FileSrc FileGrn FileDbs FileLog FileRes NCPUG`"
  for the parallel version.

The meaning of the above arguments is the following:

- `FileInp`: Name (including path) of the control input file (see section 4.1).
- `FileSrc`: Name (including path) of the source input file (see section 4.2).
- `FileGrn`: Name (including path) of the granulometry input file (see section 4.3).
- `FileDbs`: Name (including path) of the database input file (see section 4.4).
- `FileLog`: Name (including path) of the output log file (see section 5.1).
- `FileInp`: Name (including path) of the FALL3D 5.1 results file (see section 5.2).
- `NCPU`: Number of CPU's.
- `NCPUG`: Number of CPU groups.

Note that filenames (and locations) are passed as a program call argument. It is highly recomended to launch FALL3D 5.1 through the script files included in the distribution.

- On a Windows OS enter the folder `Fall3d-5.1/Scripts`, edit the script `Script-Fall3d-Win.bat` to change the "problemname" variable and launch it.
- On a Mac X/Unix/Linux OS enter the folder `Fall3d-5.1/Scripts`, edit the script `Script-Fall3d-Ser` (serial version) or the script `Script-Fall3d-Par` (parallel version) to change the "problemname" variable and launch it.

NOTE: To create a new run you can simply create a new folder, copy the control input file of the example (Example.inp) and modifiy the script line which defines the "problemname" variable.

# 4 The FALL3D 5.1 input files

## 4.1 The control file `FileInp`

The FALL3D 5.1 control file is passed to the program as a call argument. The control input file is made up with a set of blocks that define all the computational and physical parameters needed by FALL3D 5.1 and the utility the programs. Each program reads only a block of the file (these could, in fact, be in separate files). Parameters within a block are listed one per record, in arbitrary order, and can optionally be followed by one or more blank spaces and a comment. Maximum allowed lenght is 256 characters. Real numbers can be expressed following the FORTRAN notation (*e.g.*, $12e7 = 12 \times 10^7$).

- `BLOCK TIME_UTC`: Defines variables related to time.
- `BLOCK FALL3D`: Defines the variables needed by FALL3D 5.1 program.
- `BLOCK GRANULOMETRY`: Defines the variables needed by SETGRN program.
- `BLOCK SOURCE`: Defines the variables needed by SETSRC program.
- `BLOCK METEO_DATABASE`: Defines the variables needed by SETDBS program.
- `BLOCK POSTPROCESS_MODELS`: Defines the variables needed by FALL3DPOSTP program.

### 4.1.1 BLOCK TIME_UTC

This block of data defines variables related to time. Table 3 shows an example of `TIME_UTC` block.

- `YEAR`: Simulation year.
- `MONTH`: Simulation month (1-12).
- `DAY`: Simulation day (1-31).
- `RUN_START_(HOURS_AFTER_00)`: Run start hour (after 0000UTC).
- `ERUPTION_END_(HOURS_AFTER_00)` : Eruption end hour (after 0000UTC). If the SETSRC program is used to generate the source term, this is the time instant at which source is switched off.
- `RUN_END_(HOURS_AFTER_00)`: Run end hour (after 0000UTC). Note that, in general, a run should continue even when the source term is switched off (*i.e.* when the eruption has stop) in order to give time for the remaining airborne particles to fall.

### 4.1.2 BLOCK FALL3D

This block of data defines the rest of variables needed by the FALL3D 5.1 program.

- `ZLAYER_(M)`: Heights (in $m$) of the $z$-layers in terrain following coordinates, *i.e.* above the vent. It is not necessary to specify the number of vertical layers since it is automatically calculated by the program. Alternatively, for regular z-layering, the user can also specify the initial value ($z_o$), the final value ($z_f$), and the increment ($\Delta z$) using the format:
`ZLAYER_(M) FROM` $z_o$ `TO` $z_f$ `INCREMENT` $\Delta z$
- `TERMINAL_VELOCITY_MODEL`: Type of terminal settling velocity model. Possibilities are `ARASTOOPOUR`, `GANSER`, `WILSON`, and `DELLINO`.
- `VERTICAL_TURBULENCE_MODEL`: Type of model for vertical diffusion. Possibilities are `CONSTANT` or `SIMILARITY`.
- `VERTICAL_DIFFUSION_COEFFICIENT_(M2/S)`: Value of the diffusion coefficient (in $m^2/s$). Only used if `VERTICAL_TURBULENCE_MODEL = CONSTANT`
- `HORIZONTAL_TURBULENCE_MODEL`: Type of model for horizontal diffusion. Possibilities are `CONSTANT` or `RAMS`.

- `HORIZONTAL_DIFFUSION_COEFFICIENT_(M2/S)`: Value of the diffusion coefficient (in $m^2/s$). Only used if `HORIZONTAL_TURBULENCE_MODEL = CONSTANT`.
- `POSTPROCESS_TIME_INTERVAL_(HOURS)`: Time interval to output results (in $h$). Results are also output at the end of the run.

## 4.2 The source file `FileSrc`

The FALL3D 5.1 source file is an ASCII file containing the definition of the source term. The source is defined at time intervals during which source values are kept constant. The number, position and values (*i.e.* Mass Flow Rate) of the source points can, however, vary from one time slice to another. There is no restriction on the number and duration of the time intervals. It allows, in practise, to discretize any type of source term. This file can be created by the utility program SETSRC . The file format is described in Table 5 and the meaning of the used symbols is the following:

- `itime1`: Starting time (in sec after 00UTC) of the time slice.
- `itime2`: End time (in sec after 00UTC) of the time slice.
- `nsrc`: Number of source points (can vary from one interval to another).
- `nc`: Number of granulometric classes.
- `MFR`: Mass flow rate (in $kg/s$).
- `x`: $x$-coordinate of the source isrc (UTM coordinates in $m$).
- `y`: $y$-coordinate of the source isrc (UTM coordinates in $m$).
- `z`: $z$-coordinate of the source isrc (terrain following coordinates in $m$, *i.e.* above the vent).
- `src`: Mass flow rate (in $kg/s$) of each granulometric class for this point source. It must be verified that $\sum\sum src(isrc, ic) = MFR$.

## 4.3 The granulometry file `FileGrn`

The granulometry file is an ASCII file containing the definition of the particle classes (a class is characterized by particle size, density and sphericity). This file can be created by the utility program SETGRN . Note that SETGRN only generates distributions which are Gaussian in $\Phi$ and linear in $\rho$ and $\psi$. FALL3D 5.1 can obviously handle with other distributions but, in this case, the granulometry file must be supplied directly by the user. The file format is described in Table 6 and the meaning of the used symbols is the following:

- `nc`: Number of particle classes.
- `diam`: Class diameter (in $mm$).
- `rho`: Class density (in $kg/m^3$).
- `sphe`: Class sphericity.
- `fc`: Class mass fraction (0-1). If must verify that $\sum$ fc $= 1$.

## 4.4 The database file `FileDbs`

The FALL3D 5.1 DataBase file is a binary file created by the SETDBS utility program. It contains the meteorological database stored in a direct access binary file. In addition to it, SETDBS creates also an ASCII file that contains the explanation of each record of the FileDbs.

# 5 The FALL3D 5.1 output files

## 5.1 The log file `FileLog`

This file contains information concerning the run (summary of input data, run time error messages, CPU time, *etc.*).

## 5.2 The results file `FileRes`

This is a binary file with the results from a FALL3D 5.1 run. This file must be processed by the FALL3DPOSTP utility to produce "human readeable" files (normally in GRD format).

# 6 The utility programs

## 6.1 The program SetGrn

The program SetGrn is an optional utility program that reads the `GRANULOMETRY` block from the control input file (`FileInp`) and generates the granulometry file for Fall3d 5.1 . It is assumed that the mass fraction of particles follows a Gaussian distribution in $\Phi$ and that the density and sphericity of particles vary linearly with $\Phi$. Note that Fall3d 5.1 can deal with more general granulometric distributions different from Gaussian. In this case, the granulometry file `FileGrn` must be supplied by the user directly, providing sizes, densities, sphericities and distribution of particles.

### 6.1.1 Program execution

To run SetGrn (see section 3.1 for installation details) type:
"`SetGrn.exe FileLog FileInp FileGrn`" (on a Unix/Linux/Mac X OS) or
"`SetGrn.win.exe FileLog FileInp FileGrn`" (on a Windows OS) where

- `FileLog`: Name (including path) of the SetGrn output log file.
- `FileInp`: Name (including path) of the control input file that contains the `GRANULOMETRY` block. Normally this file coincides with the Fall3d 5.1 input file.
- `FileGrn`: Name (including path) of the granulometry file. This is the output from SetGrn that is used later by Fall3d 5.1 as input.

Note that filenames are passed as a program call argument. It is highly recomended to launch SetGrn through the script files included in the distribution.

- On a Windows OS go to the folder `Fall3d-5.1/Scripts`, edit the script `Script-SetGrn-Win.bat` to change the "problemname" variable and launch it.
- On a Mac X/Unix/Linux OS enter the folder `Fall3d-5.1/Scripts`, edit the script `Script-SetGrn-Unix` to change the "problemname" variable and launch it.

### 6.1.2 The GRANULOMETRY block

This block of data (see Table 7) defines the variables needed by the SetGrn program. Commonly this block is appended to Fall3d 5.1 control input file. The meaning of each record is the following:

- `NUMBER_OF_CLASSES`: Number of granulometric classes.
- `FI_MEAN`: Mean value of $\Phi$ (Gaussian distribution).
- `FI_DISP`: Value of $\sigma$ in the Gaussian distribution.
- `FI_RANGE`: Minimum and maximum values of $\Phi$ ($\Phi_{min}$ and $\Phi_{max}$ respectively).
- `DENSITY_RANGE`: Values of density (in $kg/m^3$) associated to $\Phi_{min}$ and $\Phi_{max}$ particles. Lineal interpolation is assumed.
- `SPHERICITY_RANGE`: Values of sphericity associated to $\Phi_{min}$ and $\Phi_{max}$ particles. Lineal interpolation is assumed.

## 6.2 The program SetDbs

The program SetDbs generates a database file needed by Fall3d 5.1 . As input it uses either a vertical profile (sounding) together with a topography file (in GRD format) or an output from the meteorological processor CALMET (version 6.2). The latter option is prefereable because CALMET generates a 3-D wind field that accounts for topographic effects and computes micrometeorological variables in the ABL that are needed by Fall3d 5.1 to estimate the eddy diffusivity tensor. Fall3d 5.1 and the database have the same horizontal discretization, but the number and the spacing of the vertical layers can be different.

### 6.2.1 Program execution

To run SetDbs (see section 3.1 for installation details) type:
"`SetDbs.exe FileLog FileInp FileDat FileDbs TypeData FileTop`" (on a Unix/Linux/Mac X OS)
or
"`SetDbs.win.exe FileLog FileInp FileDat FileDbs TypeData FileTop`"(on a Windows OS) where

- `FileLog`: Name (including path) of the SetDbs output log file.
- `FileInp`: Name (including path) of the control input file that contains the `METEO_DATABASE` block. Normally this file coincides with the Fall3d 5.1 input file.
- `FileDat`: Name (including path) of the meteo data file. This is either the vertical profile file or the binary output from CALMET (version 6.2) depending on the value of `TypeData`
- `FileDbs`: Name (including path) of the DataBase file. This is the output from SetDbs that is used later by Fall3d 5.1 as input.
- `TypeData`: Flag to indicate the origin of meteorological data. Possibilities are `PROFILE` or `CALMET62`.
- `FileTop`: Name (including path) of the GRD topography file.

Note that filenames are passed as a program call argument. It is highly recomended to launch SetDbs through the script files included in the distribution.

- On a Windows OS go to the folder `Fall3d-5.1/Scripts`, edit the script `Script-SetDbs-Win.bat` to change the "problemname" variable and it.
- On a Mac X/Unix/Linux OS enter the folder `Fall3d-5.1/Scripts`, edit the script `Script-SetDbs-Unix` to change the "problemname" variable and launch it.

### 6.2.2 The METEO_DATABASE block

This block of data (see Table 8) defines the variables needed by SetDbs . Commonly this block is appended to the Fall3d 5.1 control input file. The meaning of each record is the following:

- `YEAR`: Simulation year.
- `MONTH`: Simulation month (1-12).
- `DAY`: Simulation day (1-31).
- `BEGIN_METEO_DATA_(HOURS_AFTER_00)`: Time (in $h$ after 0000UTC) at which meteorological data start.
- `END_METEO_DATA_(HOURS_AFTER_00)`: Time (in $h$ after 0000UTC) at which meteorological data ends. The meteo time slice should include the simulation time slice defined by the records `RUN_START_(HOURS_AFTER_00)` and `RUN_END_(HOURS_AFTER_00)` of the `TIME_UTC` block.
- `TIME_STEP_METEO_DATA_(MIN)`: Time step (in $min$) of the meteo data.
- `X_ORIGIN_(UTM_M)`: $x$-coordinate of the grid (UTM coordinates in $m$).
- `Y_ORIGIN_(UTM_M)`: $y$-coordinate of the grid (UTM coordinates in $m$).
- `CELL_SIZE_(KM)`: Horizontal spatial discretization (in $km$).
- `NX`: Number of grid cells in the $x$-direction (for both Fall3d 5.1 and SetDbs ).
- `NY`: Number of grid cells in the $y$-direction (for both Fall3d 5.1 and SetDbs ).
- `ZLAYER_(M)`: Heights (in $m$) of the database $z$-layers. If `TypeData` is `PROFILE` then SetDbs interpolates the measured values of velocity and temperature at these heights. If `TypeData` is `CALMET62` the heights represent the CALMET cell faces. Note that the vertical discretizations of SetDbs and Fall3d 5.1 can differ. The latter is defined in the record `ZLAYER_(M)` of the `FALL3D` block.

### 6.2.3 The meteo data file `FileDat`

If `TYPE_OF_DATA = CALMET` this is the (binary) calmet output file. On the contrary, if `TYPE_OF_DATA = PROFILE` this is an ASCII file containing the definition of the vertical wind profile. In this case, the file format is described in Table 9 and the meaning of the used symbols is the following:

- `itime1`: Starting time (in sec after 00UTC) of the meteo data time slice.
- `itime2`: End time (in sec after 00UTC) of the meteo data time slice.
- `nz`: Number of vertical layers.
- `z`: Vertical coordinate of the layer (in $m$, terrain following).
- `ux`: wind $x$-velocity (in $m/s$).
- `uy`: wind $y$-velocity (in $m/s$).
- `T`: Air temperature (in $^oC$).

### 6.2.4 The topography file `FileTop`

This is a file in GRD format containing the topography, typically at a regional scale. It is used by SetDbs program only when `TYPE_OF_DATA = PROFILE`. The computational domain must lay within the bounds of the topography file. The GRD file format is described in Table 10 and the meaning of the used symbols is the following:

- `nx`: Number of cells in the $x$-direction.
- `ny`: Number of cells in the $y$-direction.
- `xo`: $x$-coordinate of the grid bottom left corner (UTM coordinates in $m$).
- `xf`: $x$-coordinate of the grid top right corner (UTM coordinates in $m$).
- `yo`: $y$-coordinate of the grid bottom left corner (UTM coordinates in $m$).
- `yf`: $y$-coordinate of the grid top right corner (UTM coordinates in $m$).
- `zmin`: Minimum value of $z$ in the domain. Not used (you can use a void value).
- `zmax`: Maximum value of $z$ in the domain. Not used (you can use a void value).
- `z`: Height (in $m$) of each grid point.

## 6.3 The program SetSrc

The distribution of sources is defined in a source file (see section 4.2). The program SetSrc is an utility that reads the SOURCE block from the control input file and generates a source file. The source term is constant for a given time interval but there is no limit on the number and duration of the time intervals. It allows, in practise, to discretize any kind of time-dependency (time-dependent mass flow rate, column height, etc.). The program admits three possibilities: point source (mass is released in a single source point), Suzuki distribution (Suzuki , 1983; Pfeiffer et al., 2005), and buoyant plume model (Bursik , 2001). The last option is more elaborated and involves the solution of the 1D radial-averaged plume governing equations that describe the convective region of an eruptive column. These equations are intimately coupled with the wind field which, for small to medium size plumes, may induce a substantial plume bent-over and subsequent variations of plume height and mass release location. For this reason, when this option switched on, the program reads the values of the wind field from a meteorological database file, computes the averaged wind direction and solves the plume governing equations for each time interval and particle class accounting for wind. Note that it introduces a time dependence in the source term even when all the eruptive parameters (mass flow rate, class fraction, etc.) are kept constant in time.

### 6.3.1 Program execution

To run SETSRC (see section 3.1 for installation details) type:
"`SetSrc.exe FileLog FileInp FileSrc FileGrn FileDbs`" (on a Unix/Linux/Mac X OS) or
"`SetSrc.win.exe FileLog FileInp FileSrc FileGrn FileDbs`" (on a Windows OS) where

- `FileLog`: Name (including path) of the SETSRC output log file.
- `FileInp`: Name (including path) of the control input file that contains the `SOURCE` block. Normally this file coincides with the FALL3D 5.1 input file.
- `FileSrc`: Name (including path) of the source file. This is the output from SETSRC that is used later by FALL3D 5.1 as input.
- `FileGrn`: Name (including path) of the granulometry file (normally generated previously by SETGRN ).
- `FileDbs`: Name (including path) of the meteo database file generated by SETDBS .

Note that filenames are passed as a program call argument. It is highly recomended to launch SETSRC through the script files included in the distribution.

- On a Windows OS go to the folder `Fall3d-5.1/Scripts`, edit the script `Script-SetSrc-Win.bat` to change the "problemname" variable and launch it.
- On a Mac X/Unix/Linux OS enter the folder `Fall3d-5.1/Sources`, edit the script `Script-SetSrc-Unix` to change the "problemname" variable and launch it.

### 6.3.2 The SOURCE block

This block of data (see Table 11) defines the variables needed by SETSRC . Commonly this block is appended to the FALL3D 5.1 control input file. The meaning of each record is the following:

- `X_VENT_(UTM_M)`: $x$-coordinate of the vent (UTM coordinates in $m$).
- `Y_VENT_(UTM_M)`: $y$-coordinate of the vent (UTM coordinates in $m$).
- `MASS_FLOW_RATE_(KGS)`: Values of the mass flow rate (in $kg/s$). One value for each time interval. The duration of each time interval is constant and given by `RUN_START_(HOURS_AFTER_00)` minus `ERUPTION_END_(HOURS_AFTER_00)` divided by the number of time intervals (automatically computed by the program from the number of values).
- `SOURCE_TYPE`: Type of source distribution. Possibilities are `POINT`, `SUZUKI` or `PLUME`.
- `HEIGHT_ABOVE_VENT_(M)`: Heights of the plume (in $m$ above the vent). One value for each time interval.
- `A`: Parameter $A$ in the Suzuki distribution. One value for each time interval. Used only if `SOURCE_TYPE = SUZUKI`.
- `L`: Parameter $L$ in the Suzuki distribution. One value for each time interval. Used only if `SOURCE_TYPE = SUZUKI`.
- `EXIT_VELOCIY_(MS)`: Magma exit velocity (in $m/s$) at the vent. One value for each time interval. Used only if `SOURCE_TYPE = PLUME`.
- `EXIT_TEMPERATURE_(K)`: Magma exit temperature (in $^oK$) at the vent. One value for each time interval. Used only if `SOURCE_TYPE = PLUME`.
- `EXIT_VOLATILE_FRACTION_(IN%)`: Magma volatile mass fraction at the vent. One value for each time interval. Used only if `SOURCE_TYPE = PLUME`.

## 6.4 The program FALL3DPOSTP

The program FALL3DPOSTP is a program that reads a FALL3D 5.1 output binary file, calculates some relevant quantities at selected heights and times, and produces elementary maps in GRD and PS formats. Files in GRD format can be readed directly by several plotting programs like the commercial software . Alternativelly, the user may also generate its own plots using functions from several free packages (*e.g.* gnuplot in FORTRAN ).

### 6.4.1 Program execution

To run FALL3DPOSTP (see section 3.1 for installation details) type:
"`Falltdpostp.exe FileLog FileInp FileRes PATHRES FileSym`" (on a Unix/Linux/Mac X OS) or
"`Falltdpostp.win.exe FileLog FileInp FileRes PATHRES FileSym`" (on a Windows OS) where

- `FileLog`: Name (including path) of the FALL3DPOSTP output log file.
- `FileInp`: Name (including path) of the control input file that contains the `POSTPROCESS_MODELS` block. Normally this file coincides with the FALL3D 5.1 input file.
- `FileRes`: Name (including path) of the FALL3D 5.1 results file. This is the output from FALL3D 5.1 that is used by as input.
- `PATHRES`: Path where the FALL3DPOSTP output files are dumped.
- `FileSym`: Name (including path) of the symbols file. This file is optionally used by FALL3DPOSTP to plot symbols and legends in the PS map files.

Note that filenames are passed as a program call argument. It is highly recomended to launch FALL3DPOSTP through the script files included in the distribution.

- On a Windows OS go to the folder `Fall3d-5.1/Scripts`, edit the script `Script-Falltdpostp-Win.bat` to change the "problemname" variable and launch it.
- On a Mac X/Unix/Linux OS enter the folder `Fall3d-5.1/Scripts`, edit the script `Script-Falltdpostp-Unix` to change the "problemname" variable and launch it.

### 6.4.2 The POSTPROCESS_MODELS block

This block of data (see Table 12) defines the variables needed by FALL3DPOSTP . Commonly this block is appended to the FALL3D 5.1 control input file. The meaning of each record is the following:

- `OUTPUT_FILES_IN_GRD_FORMAT`: Possibilities are YES or NO. If YES, FALL3DPOSTP plots files in GRD format. Files in GRD format can be readed directly by several plotting programs like the commercial software GRAPHER. Alternativelly, the user may also generate its own plots using functons from several free packages (*e.g.* gnuplot in FORTRAN).
- `OUTPUT_FILES_IN_PS_FORMAT`: Possibilities are YES or NO. If YES, FALL3DPOSTP plots files in PS format.
- `MAP_TOTAL_LOAD`: Possibilities are YES or NO. If YES FALL3DPOSTP plots the total ground load.
- `UNITS`: Units of `MAP_TOTAL_LOAD`. It must be KG/M2.
- `CONTOUR_LEVELS`: Values of the contour levels for `MAP_TOTAL_LOAD`. Only used when `OUTPUT_FILES_IN_PS_FORMAT` is YES.
- `MAP_CLASS_LOAD`: Possibilities are YES or NO. If YES FALL3DPOSTP plots the class ground load.
- `UNITS`: Units of `MAP_CLASS_LOAD`. It must be KG/M2.
- `CONTOUR_LEVELS`: Values of the contour levels for `MAP_CLASS_LOAD`. Only used when `OUTPUT_FILES_IN_PS_FORMAT` is YES.

- MAP_DEPOSIT_THICKNESS: Possibilities are YES or NO. If YES Fall3dPostp plots total deposit thickness.
- UNITS: Units of MAP_DEPOSIT_THICKNESS. Possibilities are MM (for $mm$), CM (for $cm$), and M (for $m$).
- COMPACTATION_FACTOR: Deposit compactation factor.
- CONTOUR_LEVELS: Values of the contour levels for MAP_DEPOSIT_THICKNESS. Only used when OUTPUT_FILES_IN_PS_FORMAT is YES.
- MAP_TOTAL_CONCENTRATION: Possibilities are YES or NO. If YES Fall3dPostp plots the total concentration at certain $z$-levels.
- UNITS: Units of MAP_TOTAL_CONCENTRATION. It must be KG/M3.
- Z_CUTS_(M): $z$-coordinates of the layers at which concentration is output.
- CONTOUR_LEVELS: Values of the contour levels for MAP_TOTAL_CONCENTRATION. Only used when OUTPUT_FILES_IN_PS_FORMAT is YES.
- MAP_Z_CUMMULATIVE_CONCENTRATION: Possibilities are YES or NO. If YES Fall3dPostp plots the $z$ cummulative concentration (vertical integration).
- UNITS: Units of MAP_Z_CUMMULATIVE_CONCENTRATION. It must be KG/M2.
- CONTOUR_LEVELS: Values of the contour levels for MAP_Z_CUMMULATIVE_CONCENTRATION. Only used when
OUTPUT_FILES_IN_PS_FORMAT is YES.
- MAP_Z_MAXIMUM_CONCENTRATION: Possibilities are YES or NO. If YES Fall3dPostp plots the maximum value of concentration along the vertical for each point. This variable can be useful for flight safety concentration tresholds.
- UNITS: Units of MAP_Z_MAXIMUM_CONCENTRATION. It must be KG/M3.
- CONTOUR_LEVELS: Values of the contour levels for MAP_Z_MAXIMUM_CONCENTRATION. Only used when OUTPUT_FILES_IN_PS_FORMAT is YES.

### 6.4.3 The symbols file FileSym

This is a file in ASCII format containing geographic information. It is optional and used by Fall3dPostp program when OUTPUT_FILES_IN_PS_FORMAT = YES to plot symbols in the PS files. The file format is described in Table 13 and the meaning of the used symbols is the following:

- xs: $x$-coordinate of the symbol (UTM in $m$).
- ys: $y$-coordinate of the symbol (UTM in $m$).
- sname: Name of the symbol as will appear in the PS file.
- scode: Symbol code. See Figure 2.

# 7 References

Arastoopour, H., Wang, C., Weil, S., 1982. Particle-particle interaction force in a diluite gas-solid system. Chem. Eng. Sci. 37 (9), 1379–1386.

Azad, A., Kitada, T., 1998. Characteristic of the air pollution in the city of Dhaka, Bangladesh in winter. Atmos. Environ. 32, 1991–2005.

Bursik, M., 2001. Effect of wind on the rise height of volcanic plumes. Geophys. Res. Lett. 18, 3621-3624.

Collins, W., Rasch, P., Boville, B., Hack, J., McCaa, J., Williamson, D., Kiehl, J., Briegleb, B., 2004. Description of the NCAR Community Atmosphere Model (CAM 3.0). Technical Report NCAR/TN-464+STR, National Center for Atmospheric Research, Boulder, Colorado.

Costa, A., Macedonio, G., Folch, A., 2006. A three-dimensional Eulerian model for transport and deposition of volcanic ashes. Earth Planet. Sci. Lett., 241 (34), 634–647.

Dellino, P., D. Mele, R. Bonasia, G. Braia, L. La Volpe, R. Sulpizio, 2005. The analysis of the influence of pumice shape on its terminal velocity, Geophys. Res. Lett., 32, L21306.

Ganser, G., 1993. A rational approachto drag prediction spherical and nonspherical particles. Powder Technology 77, 143–152.

Jacobson, M., 1999. Fundamentals of atmospheric modelling, 1st Edition. Cambridge University Press, New York.

Pfeiffer, T., Costa, A., Macedonio, G., 2005. A model for the numerical simulation of tephra fall deposits. J. Volcanol. Geotherm. Res. 140, 273–294.

Pielke, R., 1974. A three dimensional numerical model of the sea breezes over south Florida. Mon. Weather Rev. 102, 115–139.

Pielke, R., Cotton, W., Walko, R., Tremback, C., Nicholls, M., Moran, M., Wesley, D., Lee, T., Copeland, J., 1992. A comprehensive meteorological modeling system-RAMS. Meteor. Atmos. Phys. 49, 69–91.

Scire, J., Robe, F., M.E., F., Yamartino, R., 2000. A User's Guide for the CALMET Meteorological Model. Tech. Rep. Version 5, Earth Tech, Inc., 196 Baker Avenue, Concord, MA 01742.

Ulke, A., 2000. New turbulent parameterization for a dispersion model in atmospheric boundary layer. Atmos. Environ. 34, 1029–1042.

Wilson, L., and T. C. Huang, 1979. The influence of shape on the atmospheric settling velocity of volcanic ash particles, Earth Planet. Sci. Lett. 44, 311–324.

Suzuki, T., 1983. A theoretical model for dispersion of tephra. In: D. Shimozuru, I. Yokoyama (Eds.), Arc Volcanism: Physics and Tectonics, Terra Scientific Publishing Company (TERRAPUB), Tokyo.

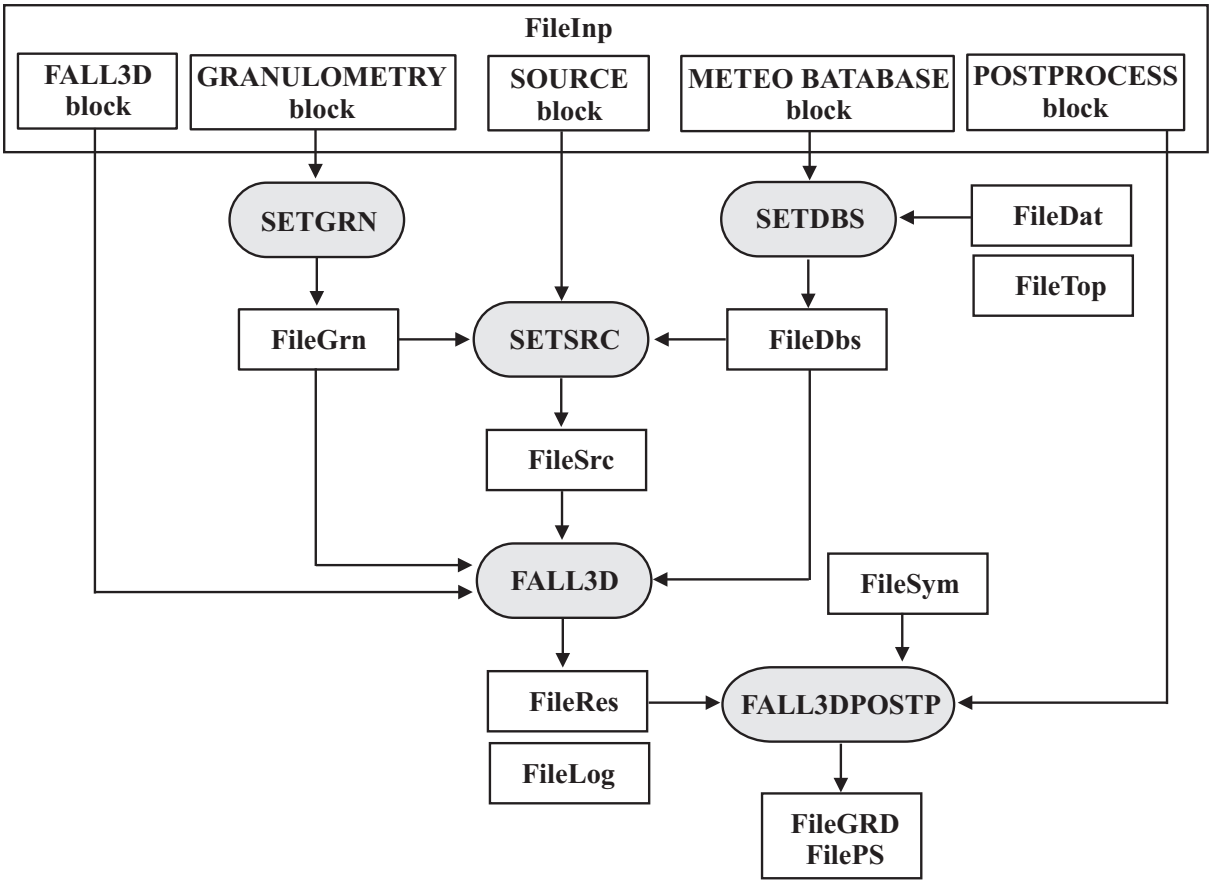


Figure 1: Execution flow for FALL3D 5.1 and the utility programs. Boxes indicate I/O files. File names are passed to programs as a call argument.

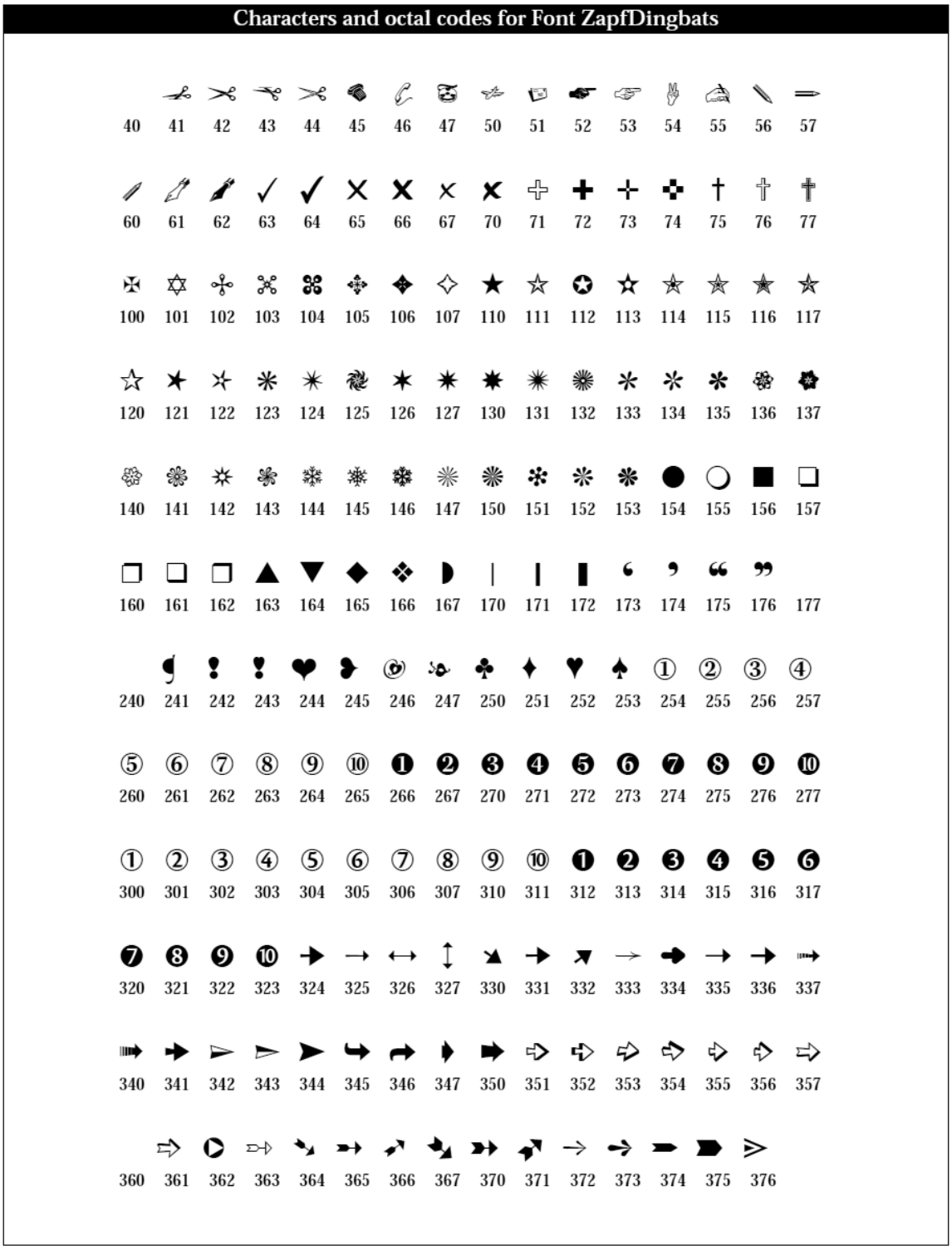


Figure 2: Symbol codes for the file `FileSym`.

| Parameter | Scaling |
|---|---|
| Coordinates | $X = x \quad Y = y \quad Z = z - h(x,y)$ |
| Velocities | $V_X = v_x \quad V_Y = v_y \quad V_Z = v_z J^{-1} \quad V_{sj} = v_{sj} J^{-1}$ |
| Diffusion Coefficients | $K_X = K_x \quad K_Y = K_y \quad K_Z = K_z J^{-2}$ |
| Concentration | $C = cJ$ |
| Density | $\rho_* = \rho J$ |
| Source Term | $S_* = SJ$ |

Table 1: Scaling factors for a terrain-following coordinate system ($x = X,\ y = Y,\ z \rightarrow Z$). $(x, y, z)$ are the Cartesian coordinates, $h$ is the topografic relief, and $J$ is the Jacobian of the coordinate system transformation.

| Level 1 | Level 2 | Level 3 | Description |
|---|---|---|---|
| Fall3d | Documents | | Contains this manual. |
| | Runs | Example | Contains the example run. |
| | Scripts | | Contains the script files. |
| | Sources | | FALL3D 5.1 sources (serial version). |
| | Sources_par | | FALL3D 5.1 sources (parallel version). |
| | Utilities | SetGrn | SETGRN utility program. See section 6.1. |
| | | SetDbs | SETDBS utility program. See section 6.2. |
| | | SetSrc | SETSRC utility program. See section 6.3. |
| | | Fall3dPostp | FALL3DPOSTP utility program. See section 6.4. |

Table 2: Default structure of FALL3D 5.1 folders.

```
TIME_UTC
YEAR = 2007
MONTH = 03
DAY = 01
RUN_START_(HOURS_AFTER_00) = 0.
ERUPTION_END_(HOURS_AFTER_00) = 3.
RUN_END_(HOURS_AFTER_00) = 6.
```

Table 3: Example of a `TIME_UTC` block of a control input file `FileInp`.

```
FALL3D
ZLAYER_(M) = 0 500 1000 2000 3000 4000 5000
TERMINAL_VELOCITY_MODEL = GANSER
VERTICAL_TURBULENCE_MODEL = SIMILARITY
VERTICAL_DIFFUSION_COEFFICIENT_(M2/S) = 100.
HORIZONTAL_TURBULENCE_MODEL = PIELKE
HORIZONTAL_DIFFUSION_COEFFICIENT_(M2/S) = 1000.
POSTPROCESS_TIME_INTERVAL_(HOURS) = 2.
```

Table 4: Example of a `FALL3D` block of a control input file `FileInp`.

| |
|---|
| itime1 itime2 |
| nsrc nc |
| MFR |
| x y z src(1,1) ... src(1,nc) |
| ... |
| x y z src(nsrc,1) ... src(nsrc,nc) |

Table 5: Format of the source file `FileSrc`. Repeat this block for each time slice

.

| |
|---|
| nc |
| diam(1) rho(1) sphe(1) fc(1) |
| ... |
| diam(nc) rho(nc) sphe(1) fc(nc) |

Table 6: Format of the granulometry file `FileGrn`.

```
GRANULOMETRY
NUMBER_OF_CLASSES = 12
FI_MEAN = 1.5
FI_DISP = 1.5
FI_RANGE = -4.  5.
DENSITY_RANGE = 900.  2600.
SPHERICITY_RANGE = 0.8 0.9
```

Table 7: Example of a `GRANULOMETRY` block. Normally this block is appended to the FALL3D 5.1 input file `FileInp`.

```
METEO_DATABASE
YEAR = 2007
MONTH = 03
DAY = 01
BEGIN_METEO_DATA_(HOURS_AFTER_00) = 0
END_METEO_DATA_(HOURS_AFTER_00) = 6
TIME_STEP_METEO_DATA_(MIN) = 60
X_ORIGIN_(UTM_M) = 450000
Y_ORIGIN_(UTM_M) = 4125000
CELL_SIZE_(KM) = 2.0
NX = 51
NY = 51
Z_LAYER_(M) = 0.  10.  40.  100.  250.  500.  1000.  2500.  5000.  7500.  10000.
```

Table 8: Sample of the SETDBS input file. Normally this block is appended at the end of the FALL3D 5.1 input file.

| |
|---|
| itime1 itime2 |
| nz |
| z(1) ux(1) ux(1) T(1) |
| ... |
| z(nz) ux(nz) ux(nz) T(nz) |

Table 9: Format of the meteo data file FileDat for the `PROFILE` case. Repeat this block for each meteo time increment.

| |
|---|
| DSAA |
| nx ny |
| xo xf |
| yo yf |
| zmin zmax |
| z(1,1) ... z(1,nx) |
| ... |
| z(ny,1) ... z(ny,nx) |

Table 10: Format of the topography file FileTop for the `PROFILE` case.

```
SOURCE
X_VENT_(UTM_M) = 500080.
Y_VENT_(UTM_M) = 4177690.
MASS_FLOW_RATE_(KGS) = 5d4 4d4          (One value for each source time interval)
SOURCE_TYPE = SUZUKI
POINT_SOURCE                            (Variables below are used only if SOURCE_TYPE = POINT)
HEIGHT_ABOVE_VENT_(M) = 2000.
SUZUKI_SOURCE                           (Variables below are used only if SOURCE_TYPE = SUZUKI)
HEIGHT_ABOVE_VENT_(M) = 3000.  2800.    (One value for each source time interval)
A = 4.  4.                              (One value for each source time interval)
L = 5.  5.                              (One value for each source time interval)
PLUME_SOURCE                            (Variables below are used only if SOURCE_TYPE = PLUME)
EXIT_VELOCIY_(MS) = 100.
EXIT_TEMPERATURE_(K) = 1073.
EXIT_VOLATILE_FRACTION_(IN%) = 0.
```

Table 11: Sample of the SetSrc input file. Normally this block is appended at the end of the Fall3d 5.1 input file. In this example a Suzuki source and two time intervals are assumed.

```
POSTPROCESS_MODELS
OUTPUT_FILES_IN_GRD_FORMAT = YES
OUTPUT_FILES_IN_PS_FORMAT = NO
MAP_TOTAL_LOAD = YES
UNITS = KG/M2
CONTOUR_LEVELS = 0.1 0.25 0.5 1.  5.  10.  50.      (Only used if OUTPUT_FILES_IN_PS_FORMAT=YES)
MAP_CLASS_LOAD = NO
UNITS = KG/M2
CONTOUR_LEVELS = 0.1 0.25 0.5 1.  5.  10.  50.      (Only used if OUTPUT_FILES_IN_PS_FORMAT=YES)
MAP_DEPOSIT_THICKNESS = NO
UNITS = MM
COMPACTATION_FACTOR = 0.7
CONTOUR_LEVELS = 0.1 1.  5.  10.  50.  100.  500.  (Only used if OUTPUT_FILES_IN_PS_FORMAT=YES)
MAP_TOTAL_CONCENTRATION = YES
UNITS = KG/M3
Z_CUTS_(M) = 1000.  2000.
CONTOUR_LEVELS = 1e-5 1e-4                          (Only used if OUTPUT_FILES_IN_PS_FORMAT=YES)
MAP_Z_CUMMULATIVE_CONCENTRATION = YES
UNITS = KG/M2
CONTOUR_LEVELS = 0.01 0.1 1.  10.                   (Only used if OUTPUT_FILES_IN_PS_FORMAT=YES)
MAP_Z_MAXIMUM_CONCENTRATION = YES
UNITS = KG/M3
CONTOUR_LEVELS = 1e-4 1e-3                          (Only used if OUTPUT_FILES_IN_PS_FORMAT=YES)
```

Table 12: Sample of the FALL3DPOSTP input file. Normally this block is appended at the end of the FALL3D 5.1 input file.

```
xs ys sname scode 1
...
```

Table 13: Format of the symbols file `FileSym`. Repeat the line for each symbol to be plotted.